

# UK Patent Application GB 2 171 942 A

(43) Application published 10 Sep 1986

(21) Application No 8602912

(22) Date of filing 6 Feb 1986

(30) Priority data

(31) 3507274

(32) 1 Mar 1985

(33) DE

(51) INT CL<sup>4</sup>  
B23C 3/18 F04D 29/32

(52) Domestic classification (Edition H):  
B3K 1E 2A4H 2A4J 2A8C 7K  
B3D FA  
F1V 104 CS CW

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(56) Documents cited  
GB 0829035 GB 0346480  
GB 0652591

(58) Field of search  
B3K  
B3D  
Selected US specifications from IPC sub-classes B23C  
B24B

(54) Cutting bladed discs especially for  
pumps

(57) Slots are sawn into the edges of  
discs 1 for a turbo-molecular pump with  
a cup saw 4. Blades having a curved  
axial cross-section result and by  
optionally providing an eccentric  
motion of the cup saw relative to the  
disc, the blades may taper inwardly or  
outwardly or have no taper. A cup saw  
comprising two coaxial toothed  
cylinders may be employed. A plurality  
of discs can be machined  
simultaneously.

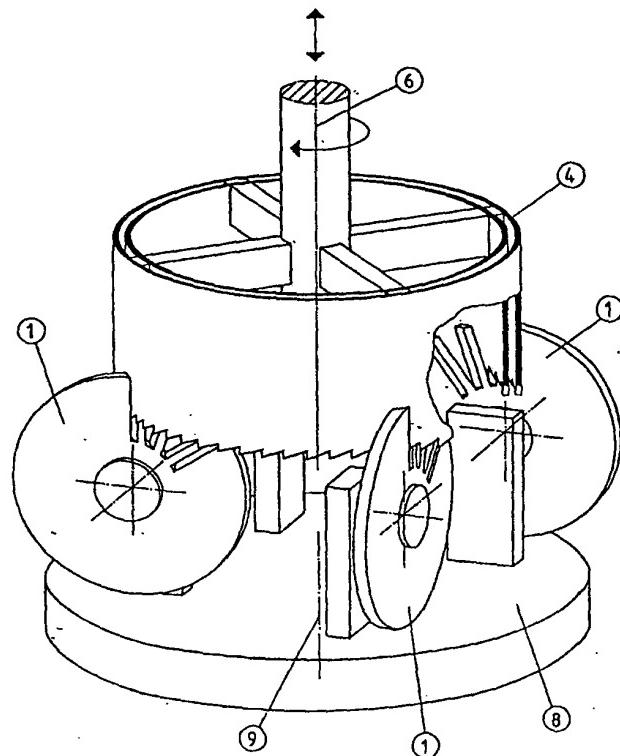


Fig 2

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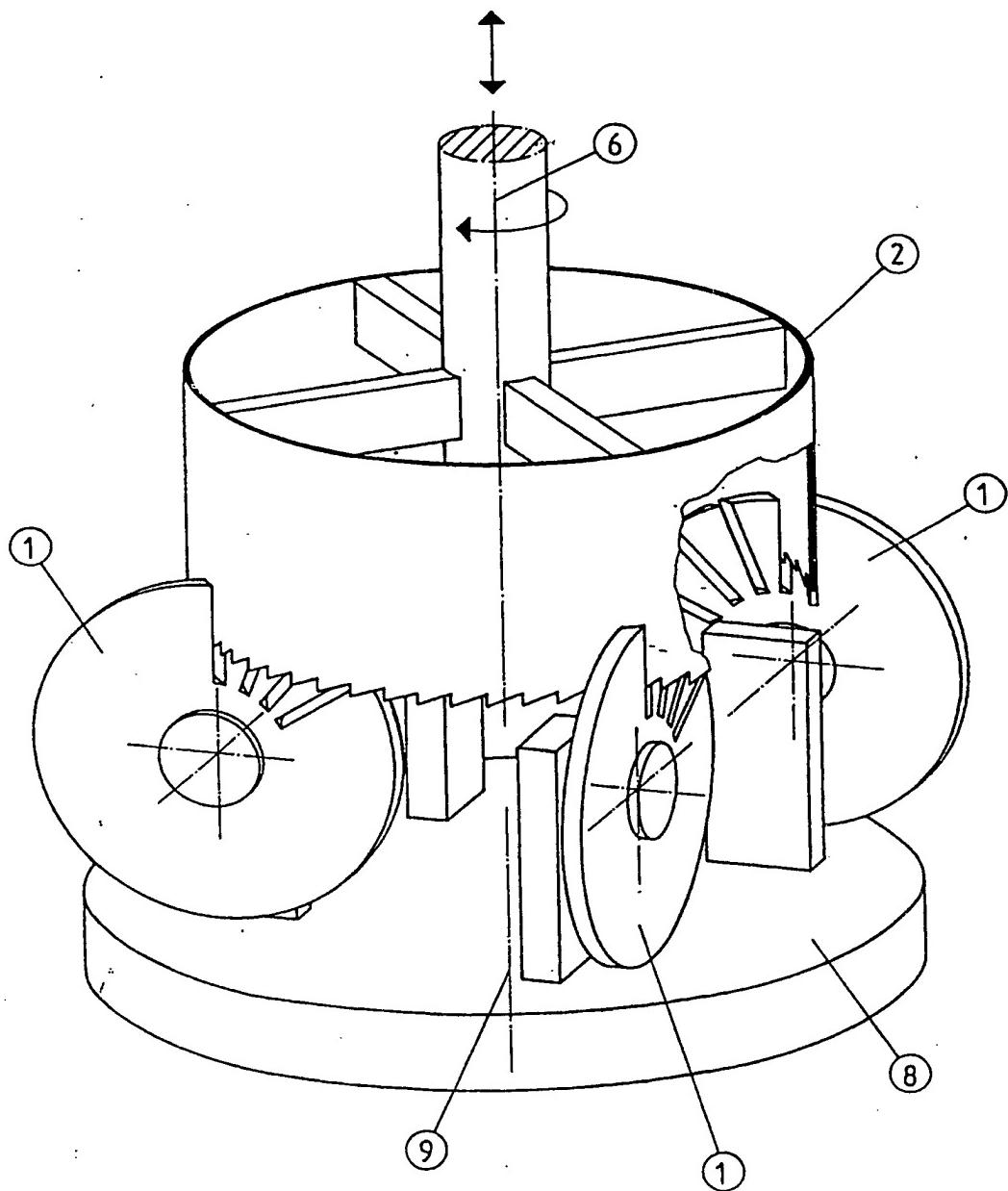


Fig 1

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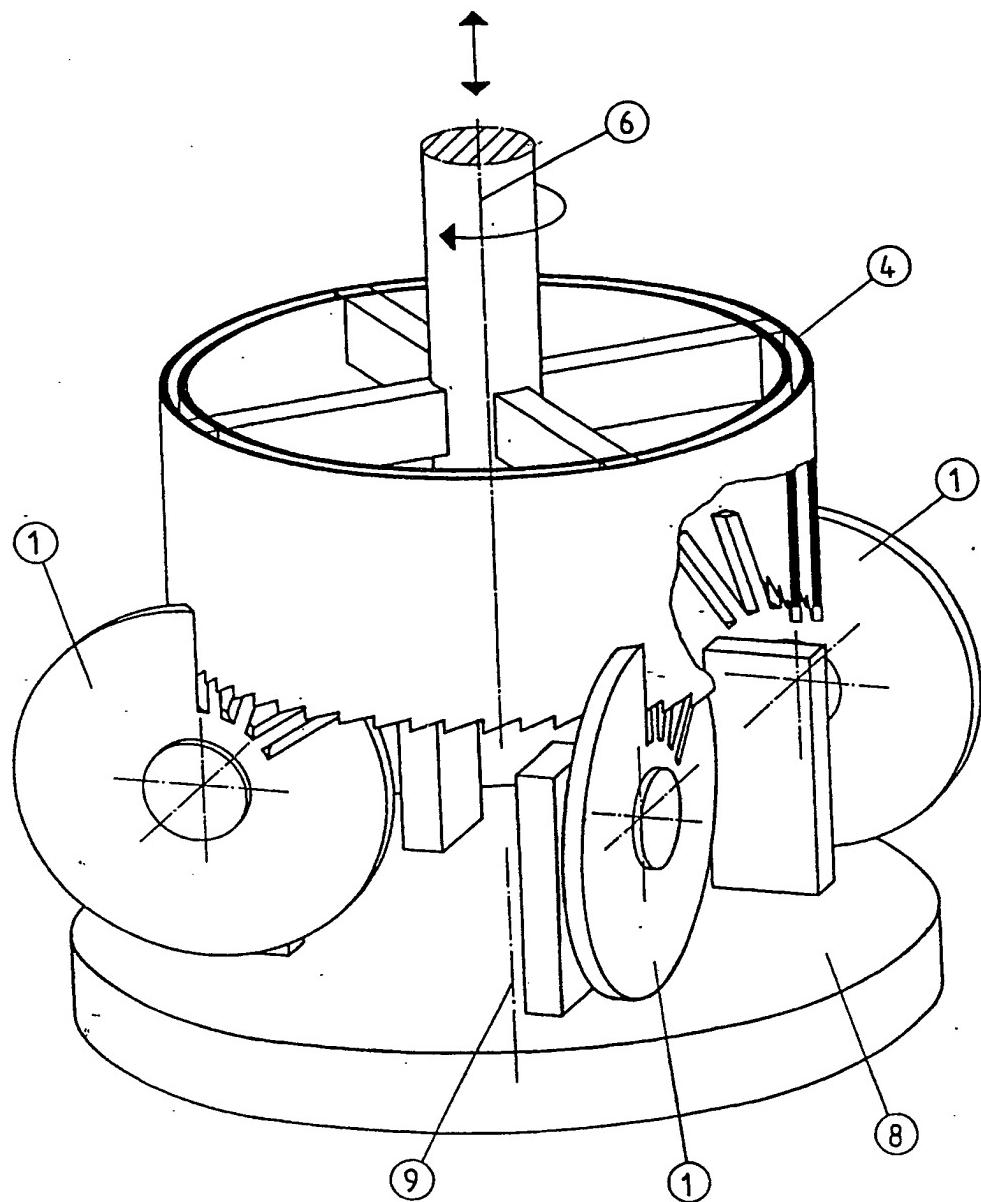


Fig 2

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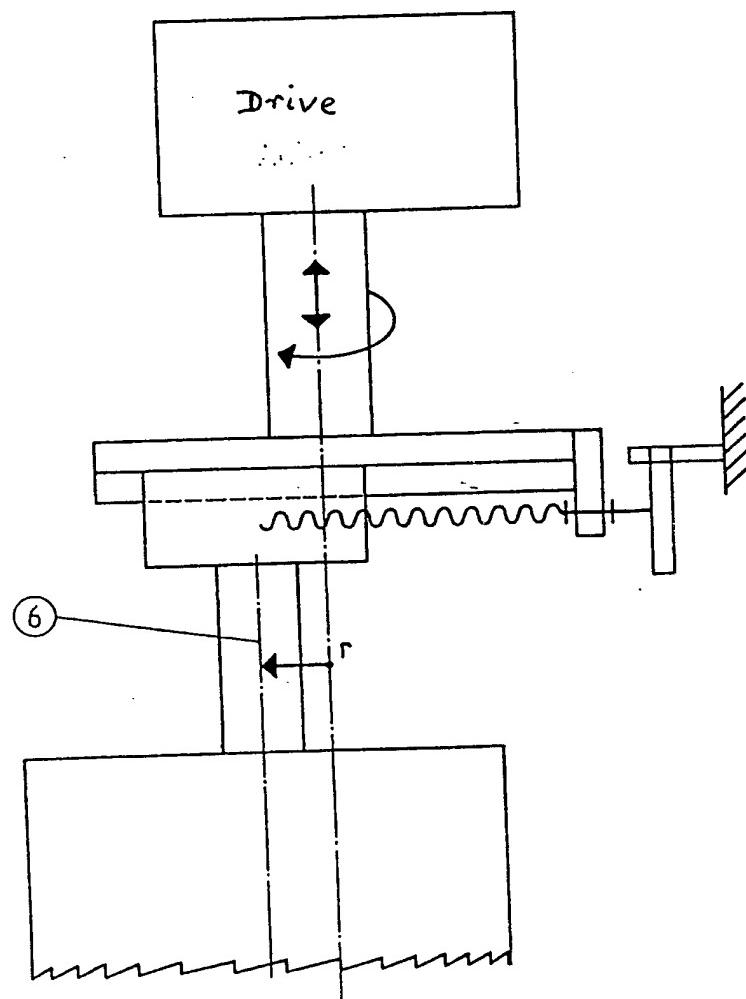


Fig 3

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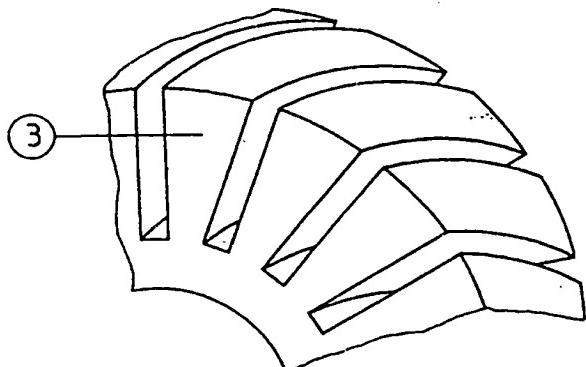


Fig 4

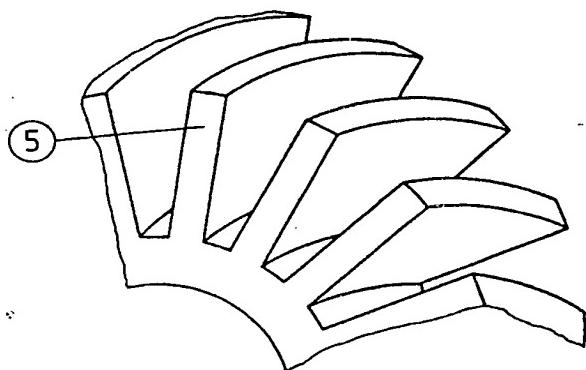


Fig 5

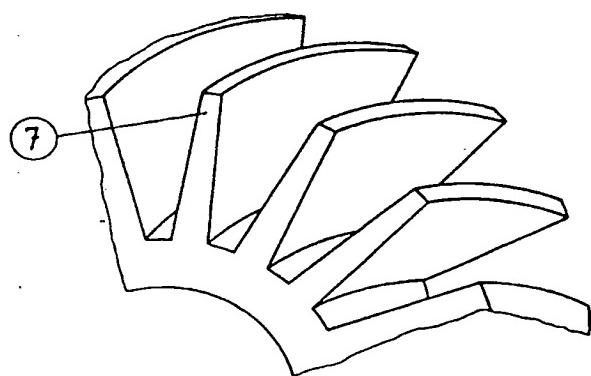


Fig 6

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SPECIFICATION

## Discs with blades, especially for pumps

5 The present invention relates to discs with radially-extending blades and a method of producing such discs. Such discs are used in pumps, especially turbo-molecular pumps.

A turbo-molecular pump is composed of rotor 10 and stator discs which are disposed alternately one behind the other and comprise rings of blades or vanes. The pump action is based on the fact that impulses in the pumping direction are transmitted to the molecules of the gas to be pumped by the 15 blades of the rotor discs. The two important pump characteristics, namely pumping speed and pressure ratio, depend very much on the speed of rotation of the rotor discs. The pumping speed increases linearly with the speed of rotation and 20 the pressure ratio does so exponentially. In order to achieve an optimum pump action therefore, the rotor must rotate at the highest possible speed. As a result, heavy demands are made on the blades of the rotor discs with regard to their geometry, mechanical strength and stability.

25 Blades for discs of turbo-molecular pumps and/or methods of producing such blades or discs are described, inter alia, in the following publications:

- 30 DE-PS 10 15 573
- DE-PS 15 03 704
- DE-PS 20 35 063
- DE-PS 20 50 555
- DE-AS 22 29 724
- DE-AS 26 54 055
- 35 DE-AS 27 17 366
- DE-OS 29 23 632
- FR-PS 12 97 182
- FR-PS 13 06 013

Becker, Nesseldreher: Neue Hochleistungsscheiben für Turbo-Molekularpumpen - Vakuum-Technik 40 23 (1973), 1 pages 12-15.

The blades proposed in these publications have a rectangular, rhombus-like or triangular cross-section or profile.

45 A prerequisite for optimum pump characteristics is a minimum thickness of the blades. This is due to the fact that, because of the desired high speed of rotation, the centrifugal force which acts on the blades, the roots of the blades and on the inner diameter of the rotor discs must be restricted to a 50 minimum for reasons of strength. Furthermore a limited blade thickness of rotor and stator discs is desired in order to make the suction space between the blades as large as possible which is one of the prerequisites for a high pumping speed.

55 A limited blade thickness however, has a disadvantageous effect on the stability of the blades. As a result of resonances, for example, which occur at certain speeds of rotation during the running up to 60 speed or running down of the rotor, oscillations may occur which can lead to contact between the blades and the stator discs, which generally leads to destruction of the pump.

65 Deformation and oscillations of the blades also occur in the event of venting phenomena which

produce heavy forces in the axial direction.

The present invention seeks to provide blades which have a high stability in comparison with previously known blades, with a minimum blade thickness and hence optimum pump characteristics. The invention also seeks to provide a method of producing such blades. In addition, the method of production should permit such blades to be manufactured rationally. This means that as large a number of discs as possible should be capable of being machined simultaneously in one operation.

According to a first aspect of the present invention there is provided a method of producing discs with radially-extending blades, wherein slots are sawn in the discs by a cup saw whereby blades are produced with a curved cross-section, the radius of curvature corresponding to the radius which the cup saw describes.

According to a second aspect of the present invention there is provided a disc with a ring of blades, wherein the blades have a circular cross-section.

By machining discs with a cup saw, blades with a curved cross-section are formed, that is to say 90 blades, the cross-section of which represents a segment of a ring. Since parallel channels are formed when sawing into the discs, the wall thickness of the blades is not equal. It decreases from the outside inwards. The strength characteristics of a disc are influenced very disadvantageously as a result because a heavy mechanical loading results at the root of the blades. In order to avoid this, blades having a uniform wall thickness are produced in that either the cup saw or the apparatus 95 to receive the discs is allowed to execute an additional movement or a cup saw is used which consists of two coaxial cylinders.

The strength characteristics of a disc can be made still more favourable by producing blades, 100 the wall thickness of which decreases from the inside outwards. In order to achieve this, the axis of the cup saw is allowed to describe a circular motion. Thus an oscillating motion results. If the radius of this circular motion is altered, blades 105 having a variable wall thickness can be produced. In particular blades, the wall thickness of which decreases from the inside outwards, result if the radius of the circular motion decreases during the sawing from the outer edge of the blade to the root of the blade.

110 Thus a rotational motion and a superimposed eccentric motion result. Since the only thing which matters is the relative motion of the tool, in this case the cup saw, and the workpiece, in this case 115 the apparatus on which the discs are mounted, it is fundamentally immaterial which part, tool or workpiece, executes one or both movements. The movement of translation in the direction of the axis can likewise be carried out equally well by the tool 120 and the workpiece.

125 The same result, namely blades, the cross-section of which decreases from the inside outwards, is obtained if the axis of the cup saw or the axis of the apparatus on which the discs are mounted rotates on a conical surface with variable pitch in-

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stead of executing a circular motion.  
In the present example of application, a cup saw is used as a tool. Any milling or grinding tool which executes the same movements as the cup saw can be used instead of a cup saw.

In preferred methods according to the invention, a plurality of discs can be machined simultaneously.

Preferred embodiments of the present invention 10 will now be described, by way of example only, with reference to the accompanying drawings, of which:

Figure 1 shows a cup saw and an apparatus for receiving the discs for use in a method according 15 to a first embodiment of the present invention;

Figure 2 shows a cup saw consisting of two coaxial cylinders and an apparatus for receiving the disc for use in a method according to a second embodiment of the present invention;

Figure 3 shows an apparatus for producing an eccentric motion;

Figure 4 shows blades having a curved cross-section and having a wall thickness which increases from the inside outwards;

Figure 5 shows blades having a curved cross-section and a uniform wall thickness; and

Figure 6 shows blades having a curved cross-section with a wall thickness decreasing from the inside outwards.

Figure 1 shows an apparatus 8 on which the discs 1 are mounted. Parallel slots are sown or cut into the discs with a cup or cylindrical saw 2. The number of discs which can be machined simultaneously varies according to the size of disc in relation to the diameter of the cup saw and according to the arrangement of the discs. The relative disposition is determined by the angle of the slots to be produced in relation to the plane of the discs. With this method, discs result having blades 3 as illustrated in Figure 4. The profile of the blades is curved. Since parallel slots are sown with this method of production, there result blades the cross-section of which increases from the inside outwards.

The arrangement in Figure 2 differs from that in Figure 1 in so far as the cup saw 4 consists of two coaxial cylinders. With this method, discs result having blades 5 as illustrated in Figure 5. The profile of the blades is curved. The wall thickness of the blades and hence their cross-section is uniform over the whole length of the blade.

If, as illustrated in Figure 3, the axis 6 of the cup saw of Figure 1 or Figure 2 is allowed to describe an arc of a circle with the variable radius  $r$ , while the radius  $r$  decreases during the sawing, then blades 7 (Figure 6) are obtained, the wall thickness of which increases from the outside inwards. The profile of these blades is likewise curved. The discs having a uniform wall thickness, illustrated in Figure 5, can also be produced with the arrangement in Figure 1 if the axis of the cup saw is allowed to describe an arc of a circle, the radius of which decreases during the sawing.

In these cases, an oscillating motion of the cup saw results as well as the rotational motion. The

same effect is obtained if one or both movements is allowed to be carried out by the apparatus 8 on which the discs are mounted instead of by the cup saw 2, 4. Here the axis 9 of the apparatus 8 rotates instead of the axis 6 of the cup saw 2, 4 describing an arc of a circle with variable radius  $r$ ; this movement is taken over by the axis 9 of the apparatus 8.

As an advantageous result of the above arrangements in accordance with the invention, there are produced discs, the blades of which have a curved cross-section. As a result, the stability of the blades is considerably improved without having to renounce the optimum pump characteristics such as are afforded by a minimum blade thickness. The wall thickness of the blades may decrease from the inside outwards as a result of which the strength characteristics are considerably improved. A more rational production is afforded as a result of the fact that a plurality of discs can be machined simultaneously.

#### CLAIMS

- 90 1. A method of producing discs with radially-extending blades, wherein slots are sown in the discs by a cup saw whereby blades are produced with a curved cross-section, the radius of curvature corresponding to the radius which the cup saw describes.
- 95 2. A method as claimed in Claim 1, wherein the axis of the cup saw executes a circular motion with a variable radius which results in an oscillating motion of the cup saw, the radius varying in such a manner that it decreases during the sawing from the outer to the inner edge of the ring of blades so that blades are formed having the same wall thickness from the root of the blade to the outer radius.
- 100 3. A method as claimed in Claim 1, wherein the discs are mounted on an apparatus having an axis parallel to the axis of the cup saw and the axis of the apparatus executes a circular motion with a variable radius which results in an oscillating motion of the apparatus, the radius varying in such a manner that it decreases during the sawing from the outer to the inner edge of the ring of blades so that blades result having the same wall thickness from the root of the blade to the outer radius.
- 105 4. A method as claimed in Claim 1, wherein the cup saw comprises two coaxial cylinders.
- 110 5. A method as claimed in Claim 1 or 4, wherein the axis of the cup saw executes a circular motion with a variable radius which results in an oscillating motion of the cup saw and blades are formed having a variable wall thickness.
- 115 6. A method as claimed in Claim 1 or 4, wherein the discs are mounted on an apparatus having an axis parallel to the axis of the cup saw and the axis of the apparatus executes a circular motion with a variable radius which results in an oscillating motion of the apparatus and blades are formed having a variable wall thickness.
- 120 7. A method as claimed in Claim 5 or 6, wherein the radius of the circular motion is varied in such a manner that it decreases from the outer
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to the inner edge of the ring of blades so that blades are formed having a cross-section increasing from the outside inwards.

8. A method as claimed in any of Claims 1 to 7,  
5 wherein a plurality of discs are machined simultaneously.

9. A method as claimed in any of Claims 1 to 8,  
wherein the apparatus on which the discs are mounted rotates instead of the cup saw.

10. 10. A method as claimed in any of Claims 1 to 9, wherein a milling or grinding tool is used instead of a cup saw.

11. A method of producing discs with radially extending blades substantially as herein described  
15 with reference to the accompanying drawings.

12. A disc with a ring of blades, wherein the blades have a circular cross-section.

13. A disc as claimed in Claim 12, wherein the blades have the same wall thickness from the root  
20 of the blade to the outer radius.

14. A disc as claimed in Claim 12, wherein the wall thickness of the blades decreases from the root of the blade to the outer radius.

15. A disc with a ring of blades substantially as  
25 herein described with reference to Figure 4, Figure 5 or Figure 6 of the accompanying drawings.

16. A turbo-molecular pump comprising at least one disc according to any of Claims 12 to 15.

17. Apparatus for producing discs with radially-extending blades comprising an apparatus for mounting at least one disc and a cup saw which is disposed relative to a disc, when mounted, so as to saw the disc to form blades with a curved cross-section.

35 18. Apparatus substantially as herein described with reference to Figure 1, Figure 2 or Figure 3 of the accompanying drawings.